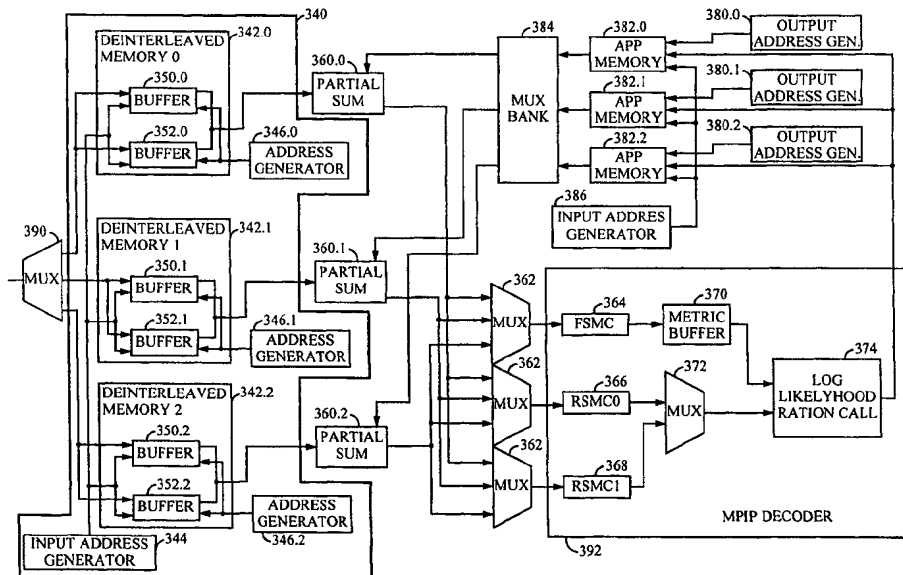




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> : H03M 13/00	A1	(11) International Publication Number: WO 00/10255 (43) International Publication Date: 24 February 2000 (24.02.00)
(21) International Application Number: PCT/US99/18551 (22) International Filing Date: 13 August 1999 (13.08.99) (30) Priority Data: 60/096,489 14 August 1998 (14.08.98) US 09/259,665 26 February 1999 (26.02.99) US (71) Applicant: QUALCOMM INCORPORATED [US/US]; 5775 Morehouse Drive, San Diego, CA 92121-1714 (US). (72) Inventor: KANG, Inyup; 4257 Calle Isabelino, San Diego, CA 92130 (US). (74) Agents: OGROD, Gregory, D. et al.; Qualcomm Incorporated, 5775 Morehouse Drive, San Diego, CA 92121-1714 (US).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

## (54) Title: PARTITIONED DEINTERLEAVER MEMORY FOR MAP DECODER



## (57) Abstract

The present invention is a novel and improved technique for decoding with particular application to turbo, or iterative, coding techniques. In accordance with one embodiment of the invention a system for decoding includes a channel deinterleaver RAM for storing a block of symbol estimates and for reading out at least three different portions of said block in substantially simultaneous fashion. A set of 3 state metric calculators receives the three portions in a substantially simultaneous fashion and generate corresponding sets of state metric calculations from said three portions of the channel deinterleaver block.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

<b>AL</b>	Albania	<b>ES</b>	Spain	<b>LS</b>	Lesotho	<b>SI</b>	Slovenia
<b>AM</b>	Armenia	<b>FI</b>	Finland	<b>LT</b>	Lithuania	<b>SK</b>	Slovakia
<b>AT</b>	Austria	<b>FR</b>	France	<b>LU</b>	Luxembourg	<b>SN</b>	Senegal
<b>AU</b>	Australia	<b>GA</b>	Gabon	<b>LV</b>	Latvia	<b>SZ</b>	Swaziland
<b>AZ</b>	Azerbaijan	<b>GB</b>	United Kingdom	<b>MC</b>	Monaco	<b>TD</b>	Chad
<b>BA</b>	Bosnia and Herzegovina	<b>GE</b>	Georgia	<b>MD</b>	Republic of Moldova	<b>TG</b>	Togo
<b>BB</b>	Barbados	<b>GH</b>	Ghana	<b>MG</b>	Madagascar	<b>TJ</b>	Tajikistan
<b>BE</b>	Belgium	<b>GN</b>	Guinea	<b>MK</b>	The former Yugoslav Republic of Macedonia	<b>TM</b>	Turkmenistan
<b>BF</b>	Burkina Faso	<b>GR</b>	Greece	<b>ML</b>	Mali	<b>TR</b>	Turkey
<b>BG</b>	Bulgaria	<b>HU</b>	Hungary	<b>MN</b>	Mongolia	<b>TT</b>	Trinidad and Tobago
<b>BJ</b>	Benin	<b>IE</b>	Ireland	<b>MR</b>	Mauritania	<b>UA</b>	Ukraine
<b>BR</b>	Brazil	<b>IL</b>	Israel	<b>MW</b>	Malawi	<b>UG</b>	Uganda
<b>BY</b>	Belarus	<b>IS</b>	Iceland	<b>MX</b>	Mexico	<b>US</b>	United States of America
<b>CA</b>	Canada	<b>IT</b>	Italy	<b>NE</b>	Niger	<b>UZ</b>	Uzbekistan
<b>CF</b>	Central African Republic	<b>JP</b>	Japan	<b>NL</b>	Netherlands	<b>VN</b>	Viet Nam
<b>CG</b>	Congo	<b>KE</b>	Kenya	<b>NO</b>	Norway	<b>YU</b>	Yugoslavia
<b>CH</b>	Switzerland	<b>KG</b>	Kyrgyzstan	<b>NZ</b>	New Zealand	<b>ZW</b>	Zimbabwe
<b>CI</b>	Côte d'Ivoire	<b>KP</b>	Democratic People's Republic of Korea	<b>PL</b>	Poland		
<b>CM</b>	Cameroon	<b>KR</b>	Republic of Korea	<b>PT</b>	Portugal		
<b>CN</b>	China	<b>KZ</b>	Kazakistan	<b>RO</b>	Romania		
<b>CU</b>	Cuba	<b>LC</b>	Saint Lucia	<b>RU</b>	Russian Federation		
<b>CZ</b>	Czech Republic	<b>LI</b>	Liechtenstein	<b>SD</b>	Sudan		
<b>DE</b>	Germany	<b>LK</b>	Sri Lanka	<b>SE</b>	Sweden		
<b>DK</b>	Denmark	<b>LR</b>	Liberia	<b>SG</b>	Singapore		
<b>EE</b>	Estonia						

## PARTITIONED DEINTERLEAVER MEMORY FOR MAP DECODER

**BACKGROUND OF THE INVENTION**

5

**I. Field of the Invention**

10 The present invention relates to channel coding. More particularly, the present invention relates to a novel and improved technique for performing maximum a posteriori (MAP) decoding.

**II. Description of the Related Art**

15 "Turbo coding" represents an important advancement in the area of forward error correction (FEC). There are many variants of turbo coding, but most use multiple encoding steps separated by interleaving steps combined with iterative decoding. This combination provides previously unavailable performance with respect to noise tolerance in a communications system.  
20 That is, turbo coding allows communications at  $E_b/N_0$  levels that were previously unacceptably using the forward error correction techniques available at that time.

Many systems use forward error correction, and therefore would benefit from the use of turbo coding. For example, turbo codes could  
25 improve the performance of wireless satellite links, where the limited downlink transmit power of the satellite necessitates receiver systems that can operate at low  $E_b/N_0$  levels. Using turbo codes in a wireless satellite link could reduce the dish size for a digital video broadcast (DVB) system, or, alternatively, allow more data to be transmitted within a given frequency  
30 bandwidth.

Digital wireless telecommunication systems, such as digital cellular and PCS telephone systems, also use forward error correction. For example, the IS-95 over-the-air interface standard, and its derivatives, such as IS-95B, define a digital wireless communications system that uses convolutional  
35 encoding to provide coding gain to increase the capacity of the system. A system and method for processing RF signals substantially in accordance with the use of the IS-95 standard is described in US patent 5,103,459 entitled "System and Method for Generating Signal Waveforms in a CDMA Cellular

Telephone System" assigned to the assignee of the present invention and incorporated herein by reference ('459 patent).

Because digital wireless communication system like IS-95 are primarily for mobile communications, it is important to have devices that minimize power usage and which are small and light weight. Typically, this requires development of a semiconductor integrated circuit ("chip") for performing most, or all, of the necessary processing. While convolutional encoding is relatively complex, the circuits necessary to perform convolutional encoding and decoding can be formed on a single chip along with any other necessary circuitry.

Turbo coding (in particular the decoding operation) is significantly more complex than convolutional encoding (and decoding). Nonetheless, it would be highly desirable to include turbo coding in digital wireless telecommunication systems, including mobile digital communication systems and satellite communication system. Thus, the present invention is directed to increasing the rate at which certain decoding operations can be performed, to facilitate the use of turbo coding in a variety of systems.

## SUMMARY OF THE INVENTION

The present invention is a novel and improved technique for decoding technique with particular application to turbo, or iterative, coding techniques. In accordance with one embodiment of the invention a system for decoding includes a channel deinterleaver RAM for storing a block of symbol estimates and for reading out at least three different portions of said block in substantially simultaneous fashion. A set of 3 state metric calculators receives the three portion in a substantially simultaneous fashion and generate corresponding sets of state metric calculations from said three portions of the channel deinterleaver block.

## BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

**FIGS. 1A and 1B** are block diagrams of wireless communication systems.

**FIG. 2** is a block diagram of an transmit system;

FIGS. 3A and 3B are diagrams of turbo coders;

FIG. 4 is a block diagram a receive processing system;

FIG. 5 is a block diagram of decoder and a portion of a channel deinterleaver;

5 FIG. 6 is a flow chart illustrating an exemplary set of decoding steps.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

10 The present invention is a novel and improved technique for performing turbo coding. The exemplary embodiment is described in the context of the digital cellular telephone system. While use within this context is advantageous, different embodiments of the invention may be incorporated in different environments, configurations or digital data  
15 transmission systems, including satellite communication systems and wire line communication system such as digital cable and telephone systems.

In general, the various systems described herein may be formed using software controlled processors, integrated circuits, or discreet logic, however, implementation in an integrated circuit is preferred. The data, instructions,  
20 commands, information, signals, symbols and chips that may be referenced throughout the application are advantageously represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or a combination thereof. In addition, the blocks shown in each block diagram may represent either hardware or method steps.

25 Fig. 1A is a highly simplified diagram of a cellular telephone system configured in accordance with one embodiment of the invention. To conduct telephone calls or other communications, subscriber units 10 interface with base stations 12 via RF signals. Base stations 12 interface with the public switch telephone network via base station controller (BSC) 14.

30 Fig. 1B is a highly simplified diagram of a satellite communications system configured in accordance with another embodiment of the invention. Uplink station 40 transmits RF signals containing information such as video programming to satellite 42. Satellite 42 relays the RF signals back to earth where receiver 44 converts the receive RF signals into digital  
35 data.

Fig. 2 is a block diagram of an exemplary transmit system configured in accordance with the use of one embodiment present invention. The transmit system can be used within a subscriber unit 10, a base stations 12, or uplink station 40, as well as any other system that generates digital signals

for transmission. The transmit processing shown represent just one possible embodiment of the invention, as numerous other transmit processing schemes may incorporate and benefit from the use of various embodiments of the invention.

5 Data 70 is supplied to CRC generator 72 which generates CRC checksum data for a given each predetermined amount of data received. The resulting data blocks are supplied to turbo coder 76 which generates code symbols that are supplied to channel interleaver 78. The code symbols typically include a retransmission of the original data (the systematic  
10 symbol), and one or more parity symbols.

The number of parity symbols transmitted for each systematic symbol depends on the coding rate. For a coding rate of  $\frac{1}{2}$  one parity symbol is transmitted for every systematic symbol, for a total of two symbols generated for each data bit (including CRC) received. For a rate  $\frac{1}{3}$  turbo coder, two  
15 parity symbols are generated for each systemic symbol, for a total of three symbols generated for each data bit received.

The code symbols from the turbo coder 76 are supplied to channel interleaver 78. Channel interleaver 78 performs interleaving on blocks the symbols as they are received, outputting interleaved symbols that are  
20 received by mapper 80. Typically, channel interleaver 78 performs block or bit-reversal interleaving, virtually all other types of interleavers may be used as the channel interleaver.

Mapper 80 takes the interleaved code symbols and generates symbol words of certain bit width based on a predetermined mapping scheme. The  
25 symbol words are then applied to modulator 82 which generates a modulated wave form based on the symbol word received. Typical modulation techniques include QPSK, 8-PSK, and 16 QAM, although various other modulation schemes may be utilized. The modulated waveform is then upconverted for transmission at an RF frequency.

30 **Fig. 3A** is a block diagram of a turbo coder configured in accordance with a first embodiment of the invention. In this first embodiment of the invention, the turbo coder is configured as a parallel concatenated turbo coder. Within the version of the turbo coder 76, constituent coder 90 and code interleaver 92 receive the data from CRC generator 72, which as  
35 described above output the input data and CRC checksum bits.

As is well known, code interleaver 92 should be a highly randomized interleaver for the best performance. An interleaver that provides excellent performance with minimal complexity as a code interleaver is described in copending US Patent Application Serial No. 09/172,069 entitled "Coding

System Having State Machine Based Interleaver" assigned to the assignee of the present application and incorporated herein by reference. Constituent coder 90 outputs systematic symbols 94 (typically a copy of the original input bits) and parity symbols 96. Constituent coder 98 receives the interleaved  
5 output of code interleaver 92 and outputs additional parity symbols 99. Tail bits may also be added, but are omitted because they are not particularly relevant to the present invention.

The outputs of constituent coder 90 and constituent coder 98 are muxed into the output data stream for a total coding rate  $R$  of  $1/3$ .  
10 Additional constituent codes and code interleaver pairs may be added to reduce the coding rate for increased forward error correction. Alternatively, some of the parity symbols 96 and 99 may be punctured (not transmitted) to increase the coding rate. For example, the coding rate could be increased to  $\frac{1}{2}$  by puncturing every other parity symbol 96 and 99, or not transmitting  
15 parity symbol 96 at all.

Constituent coders 90 and 98 may be various types of coders including block coders or convolutional coders. As convolutional coders, constituent coders 90 and 98 typically have a small constraint length such as 4 (four) to reduce complexity, and are recursive systematic convolutional (RSC)  
20 encoders. The lower constraint length reduces the complexity of the corresponding decoder at the receive system.

Typically, the two coders output one systematic symbol and one parity symbol for each bit received for a constituent coding rate  $R = \frac{1}{2}$ . The total coding rate for the turbo coder of Fig. 1A is  $R = 1/3$ , however, because the  
25 systematic bit from constituent coder 98 is not used. As noted above, additional interleaver and coder pairs may also be added in parallel to reduce the coding rate, and therefore provide higher error correction, or puncturing can be performed to increase the coding rate.

Fig. 3B depicts turbo coder 76 as a serial concatenated turbo coder in  
30 accordance with an alternative embodiment of the invention. Within the turbo coder of Fig. 3B, the data from CRC generator 72 is received by constituent coder 110 and the resulting code symbols are applied to code interleaver 112. The resulting interleaved parity symbols are supplied to constituent coder 114, which performs additional encoding to generate  
35 parity symbols 115. Typically, constituent coder 110 (the outer coder) may be various types of encoders including block encoders or convolutional encoders, but constituent coder 114 (the inner coder) is preferably a recursive coder and is typically a recursive systematic encoder.

As recursive systematic convolutional (RSC) encoders, constituent coders **110** and **114** generate symbols at a coding rate  $R < 1$ . That is, for a given number of input bits  $N$ ,  $M$  output symbols are generated where  $M > N$ . The total coding rate for the serial concatenated turbo coder of **Fig. 1B** is the coding rate of constituent coder **110** multiplied by the coding rate of constituent coder **114**. Additional interleaver and coder pairs may also be added in series to reduce the coding rate and therefore provide additional error protection.

**Fig. 4** is a block diagram of a receive system configured in accordance with one embodiment of the invention. Antenna **150** provides the received RF signals to RF unit **152**. RF unit performs downconversion, filtering, and digitization of the RF signals. Mapper **140** receives the digitized data and provides soft decision data to channel deinterleaver **156**. Turbo decoder **158** decodes the soft decision data from channel deinterleaver **156** and supplies the resulting hard decision data to the processor or control unit at the receive system, which can check the accuracy of the data using the CRC checksum data.

**Fig. 5** is a block diagram of turbo decoder **158** and a portion of the channel deinterleaver when configured in accordance with one embodiment of the invention. As shown, turbo decoder **158** is configured for decoding the data from the turbo coder shown in **Fig. 3A**.

In the described embodiment, channel deinterleaver portion **340** includes deinterleaver memory banks **342.0 - 342.2**. Together deinterleaver memory banks **342.0 - 342.2** form the entire deinterleaver memory. Deinterleaver memory banks **340** are double buffered in one embodiment of the invention, and include a first buffer **350** and a second buffer **352**. During normal operation, one buffer is available for writing into while the other buffer is available for reading out. Also, double buffering allows the channel interleaver memory to be used, along with the app memory, as the turbo deinterleaver memory.

Symbol estimates to be deinterleaved are received and written into (one buffer) of each deinterleaver memory **342** via multiplexer **390**. When data is being written in, input address generator **344** controls the buffer receiving the symbol estimates.

In a preferred embodiment of the invention, symbol estimates are written into only one deinterleaver memory **340** at any particular time. Each deinterleaver memory **340** receives a portion of the total number of symbol estimates in the interleaver block. That is, deinterleaver memory **340.0** receives a first portion of the symbol estimates in the channel



interleaver block, deinterleaver memory 340.1 receives a second portion of the symbol estimates in the channel interleaver block, and deinterleaver memory 340.2 receives a third portion of the symbol estimates in the channel interleaver block.

5 In one embodiment of the invention, one deinterleaver memory 340 receives the first of every third (1<sup>st</sup> of 3) "window" of symbol estimates in the channel interleaver block. A window is just a predetermined number (L) of symbol estimates related to the decoding process as described below. Another deinterleaver memory 340 receives the second of every third (2<sup>nd</sup> of 3) window of symbol estimates and the third deinterleaver memory receives the third of every third (3<sup>rd</sup> of 3) window of symbol estimates. As should be apparent, the window L of symbol estimates is smaller than the size of the interleaver block. Multiplexer 390 directs the symbol estimates to the particular deinterleaver memory 340.

15 In an exemplary processing, a first window (1L) of symbol estimates is first written into deinterleaver memory 342.0. The second window (2L) of symbol estimates is written into deinterleaver memory 342.1, and the third window (3L) of symbol estimates is written into deinterleaver memory 342.2. This pattern is repeated for all subsequent windows of symbol estimates, so that the every 3NL (where N is an integer) window of symbol estimates is written into deinterleaver memory 340.0, and every 3NL+1 window of symbol estimates are written into deinterleaver memory 340.1 and every 3NL + 1 window of symbol estimates is written into deinterleaver memory 340.2. Table I provides a list of the symbol estimates (number from 20 0 to N) stored in each deinterleaver memory 340.

Memory 0	Memory 1	Memory 2
0 - L-1	L - 2L-1	2L - 3L-1
3L - 4L-1	4L - 5L-1	5L - 6L-1
...	...	...
3NL - (3N+1)L-1	3(N+1)L - 3(N+2)L-1	3(N+2)L - 3NL-1

Table I.

30 While symbol estimates for the current interleaver block are written into deinterleaver memories 340, the previously received block of estimates are read out from deinterleaver memory 340 to partial sum circuits 360.0 - 360.2 using the double buffering scheme as described above. In contrast to

the writing process, during reading the three deinterleaver memories are preferably read out in substantially simultaneous fashion under the control of address generators 346.0 - 346.2.

Partial sum circuits 360.0 - 360.2 receive the symbol estimates (also  
5 know as soft decision data) from each deinterleaver memory as well as *a priori* (APP) data from APP memories 382 via multiplexer bank 384. As is well known in the art of turbo, and turbo-like, coding the APP values are the estimates of the data transmitted based on the previous decoding iteration. During the first decoding iteration, the APP values are set to an  
10 unknown intermediate state. More discussion on the APP values is provided below.

The symbol estimates from the channel deinterleaver memories include estimates of the systematic symbol as well as estimates of two parity symbols for each data bit associated with the channel interleaver block.  
15 Partial sum circuits 360.0 - 360.2 add the APP value to the systematic symbol, to create "refined systematic estimates."

The refined systematic estimates, along with a party symbol estimates, from each partial sum circuit 360 are applied to multiplexers 362. For some code rates, punctures symbols are replaced with intermediate values.  
20 multiplexers 362 apply windows of symbol estimates from each deinterleaver memory 342 to each state metric calculator (e.g. forward state metric calculator (FSMC) 364, and reverse state metric calculators 366 and 368.) That is, the symbol estimates from each deinterleaver memory are read three times and, by way of partial sum circuits 360, applied sequentially  
25 to one of FSMC 364, RSMC 366, or RSMC 367 so that each set of estimates is applied to each metric calculator once. In this way, a set of forward state metrics and reverse state metrics are generated for each window. The forward state metrics and reverse state metrics are used to generate soft decision estimates of the transmitted pre-encoded information.

30 Table II provides a more detailed exemplary processing of the symbol estimates. In particular, the deinterleaver memory 342 applied to each state metric calculator (SMC) during each read cycle (by multiplexers 362) are listed, along with the set of L samples contained in that deinterleaver memory.

Cycle SMC	-1	2	3	4	5	6	7
FSMC	DEINT MEM 0; 0->L-1	DEINT MEM 1; L->2L-1	DEINT MEM 2; 2L->3L-1	DEINT MEM 0; 3L->4L-1	DEINT MEM 1; 4L->5L-1	DEINT MEM 2; 5L->6L-1	
RSMC 0	<i>DEINT</i> <i>MEM 1</i> ; 2L-1->L	DEINT MEM 0 L-1->0	<i>DEINT</i> <i>MEM 0</i> 4L-1->3L	DEINT MEM 2; 3L-1->2L	<i>DEINT</i> <i>MEM 2</i> ; 6L-1->5L	DEINT MEM 1; 5L-1->4L	
RSMC 1		<i>DEINT</i> <i>MEM 2</i> ; 3L-1->2L	DEINT MEM 1 2L-1->L	<i>DEINT</i> <i>MEM 1</i> 5L-1->4L	DEINT MEM 0 4L-1->3L		DEINT MEM 2 6L-1->5L
LLR		L-1->0	2L-1->L	3L-1->2L	4L-1->3L	5L-1->4L	6L-1->5L

Table II.

5 As illustrated by Table II, In the described embodiment of the invention, a sliding window architecture is employed for performing soft-input-soft-output (SISO) log-Maximum A Posteriori (log-MAP) decoding. A system and method for performing this sliding window MAP decoding is described in copending US patent application serial no 08/743,688 entitled

10 "Soft Decision Output Decoder for Decoding Convolutionally Encoded Codewords" assigned to the assignee of the present invention and incorporated herein by reference.

In that patent application, the MAP decoding is performed on the windows of symbol estimates as mention above. In the described

15 embodiment of the invention, are L bits in size, where L is the number of transmitted data bits in the window. A refined systematic symbol estimate and two parity symbols estimates are generated for each data bit to be decoded. In one embodiment of the invention, six (6) bits are used for the two parity symbol estimates and seven (7) bits are used for the refined

20 systematic symbol estimates (which as described above is the summation of the receive systematic symbol estimate and the APP value).

A window is processed once in the forward direction and once in the reverse direction in accordance with the MAP processing described in the above referenced patent application. Additionally, most windows are

25 processed an additional time in the reverse direction to generate an

initialization state for the other reverse state metric processing. In Table II, the initialization passes are denoted by the italicized text.

In the described embodiment, each set of estimates is processed three times, and therefore the deinterleaver memory 342 in which the estimates  
5 are stored is accessed three times. Separating the entire interleaver block of symbol estimates into three different deinterleaver memories 342, particularly as described above, allows highly parallel sliding window MAP decoding to be performed without RAM contention.

It should also be noted that Table II illustrates the coupling performed  
10 for six (6) windows of data. Thus, the exemplary channel interleaver block size is  $6L$ , and the channel deinterleaver memory is  $6L \times q$ . The channel interleaver block size of  $6L$  is for example only, and the typical channel block size will be larger than  $6L$ .

Still referring to Fig. 5, during the first read cycle, and within MAP  
15 decoder 392, FSMC 364 receives the estimates from deinterleaver memory 342.0 (by way of partial sum circuit 360.0 and multiplexer 362). FSMC 364 calculates forward state metric values over a window  $L$ . The forward state metric values are stored in metric buffer 370. Additionally, as shown in Table I, RSMC 366 calculates reverse state metric values during the first  
20 processing cycle on another window  $L$  of symbol estimates. It should be noted that in one embodiment of the invention, each state metric calculator contains its own branch metric calculator. In other embodiments of the invention, a single time shared branch metric calculator may be used by the set of state metrics.

MAP decoder is preferably a log-MAP decoder, which operates on the  
25 logarithm of the estimates rather to reduce the number of multiply operations. One implementation of a log-MAP decoder including state metric and branch metric calculators is described in the reference S.S. Pietrobon, "Implementation and Performance of a Turbo/MAP Decoder,"  
30 submitted to the *International Journal of Satellite Communications*, Jan-Feb, 1998, vol. 1, pp23-4b.

During the next processing cycle, RSMC 368 calculates reverse state  
metric values as RSMC 366 did in the previous processing cycle (training state metrics). RSMC 366 performs a reverse state metric calculation on the  
35 window  $L$  for which forward state metrics have already been calculated and stored in metric buffer 370 during the first processing cycle. As the reverse state metrics are calculated, they are forwarded, via multiplexer 372, to the log likelihood ratio (LLR) calculator 374. LLR calculator 374 performs a log likelihood calculation of the reverse state metrics received from mux 372

and the forward state metrics stored in metric buffer 370. The resulting data estimates from LLR 374 are forwarded to APP memories 382.0 - 382.2.

By using a sliding metric calculation process, the amount of memory used to perform the necessary processing is reduced. In particular, only one  
5 window L of forward state metrics need to be stored within metric buffer 276 at any given time. This is in contrast to storing metrics for the entire channel interleaver block which would require prohibitively large amounts of memory.

Additionally, the use of three metric calculators significantly  
10 increases the rate at which decoding can be performed. The rate is increased, because the initialization and decoding functions can be performed in parallel.

The data estimates from LLR 374 are written into APP memories 382 under the control of input address generator 386. Each APP memory 382  
15 receives a portion of all the data estimates generated for the interleaver block being processed.

Once the data estimates are written in, another iteration is performed where the original symbol estimates are processed again using the data estimates (also known as APP values) generated during the previous  
20 decoding. The APP values are read out of APP memories 382 in substantially simultaneous fashion under the control of output address generators 380.0 - 380.2. Mux bank 384 couples APP memories 382 to partial sum circuits 360 such that the corresponding symbol estimate and data estimate are partially summed. Once a sufficient number of decoding  
25 iterations are performed, the resulting data estimates are used to generate hard decisions.

**Fig. 6** is a flow chart illustrating the steps performed during a decoding iteration in accordance with one embodiment of the invention. In this flow chart, deinterleaver memories 342.0 - 342.2 are referred to as  
30 MEM[0] - MEM[2] respectively. Additionally, RSMC 366 is referred to as RSMC 0, and RSMC 368 is referred to as RSMC 1. An index value j is used to designate the particular deinterleaver memory (MEM) accessed at each step, but the use a value j is not necessary to practice the invention.

The decoding begins at step 400 and at step 402 the index value j is set  
35 to zero (0). Also at step 402, the forward state metric calculator 364 (FSMC) processes symbol estimates from MEM[0] and RSMC 0 processes symbol estimates from MEM[1].

At step 404 index j is incremented, and at step 408 it is determined if (j2) is less than the (of symbols estimates (MAX\_WINDOW\_INDEX) in the

interleaver block. If so, FSMC processes symbol estimates from  $\text{MEM}[j \bmod 3]$ , RSMC 0 processes symbol estimates from  $\text{MEM}[(j-1) \bmod 3]$ , and RSMC 1 processes symbol estimates from  $\text{MEM}[(j+1) \bmod 3]$  at step 410. Once step 410 is performed,  $j$  is incremented at step 412 and at step 413 it is determined if  $j \geq \text{MAX\_WINDOW\_INDEX}$  and step 414 is performed.

At step 414, FSMC processes symbol estimates from  $\text{MEM}[j \bmod 3]$ , RSMC 0 processes symbol estimates from  $\text{MEM}[(j+1) \bmod 3]$ , and RSMC 1 processes symbol estimates from  $\text{MEM}[(j-1) \bmod 3]$ . Once step 414 is performed processing returns to step 404.

If it is determined at step 408 or step 413 that  $j + 2$  is not less than  $\text{MAX\_WINDOW\_INDEX}$  step 416 is performed. At step 416 FSMC processes symbol estimates from  $\text{MEM}[j \bmod 3]$ , RSMC 0 processes symbol estimates from  $\text{MEM}[(j-1) \bmod 3]$ . At step 418  $j$  is incremented. At step 420 RSMC 1 processes symbol estimates from  $\text{MEM}[j \bmod 3]$ . The processing for the iteration is then terminated at step 424.

Thus, a novel and improved technique for performing turbo coding has been described. The previous description is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

**WHAT IS CLAIMED IS:**

## CLAIMS

1. A system for decoding comprising:
  - a) channel deinterleaver RAM for storing a block of symbol estimates and for reading out at least three different portions of said block in substantially simultaneous fashion;
  - b) set of 3 state metric calculators, each state metric calculator for generating a set of state metric calculations;
  - c) multiplexer bank for coupling said set of 3 state metric calculators to said at least three different portion of said block.
2. The system as set forth in claim 1 wherein said channel deinterleaver RAM is comprised of:
  - first deinterleaver ram for storing a first portion of said block of symbol estimates and for reading out said first portion of said block of symbol estimates;
  - second deinterleaver ram for storing a second portion of said block of symbol estimates and for reading out said second portion of said block of symbol estimates;
  - third deinterleaver ram for storing a third portion of said block of symbol estimates and for reading out said third portion of said block of symbol estimates.
3. The system as set forth in claim 2 wherein said state metric calculators processes windows of said symbol estimates, and said first portion includes every first window of three windows of said block;  
said second portion includes every second window of three windows of said block;  
said third portion includes every third of three windows of said block.
4. A system for performing turbo decoding comprising:
  - channel deinterleaver RAM for storing a block of symbol estimates and for reading out at least three different portions of said block in substantially simultaneous fashion;

set of 3 state metric calculators, each state metric calculator for  
6 generating a set of state metric calculations;  
multiplexer bank for coupling said set of 3 state metric calculators to  
8 said at least three different portion of said block;  
app memory for storing a priori values and for reading out at least  
10 three different portion of said a priori value in substantially simultaneous  
fashion.

5. The system as set forth in claim 1 wherein said channel  
2 deinterleaver RAM is comprised of:  
first deinterleaver ram for storing a first portion of said block of  
4 symbol estimates and for reading out said first portion of said block of  
symbol estimates;  
6 second deinterleaver ram for storing a second portion of said block of  
symbol estimates and for reading out said second portion of said block of  
8 symbol estimates;  
third deinterleaver ram for storing a third portion of said block of  
10 symbol estimates and for reading out said third portion of said block of  
symbol estimates.

6. The system as set forth in claim 4 wherein said state metric:  
2 calculators processes windows of said symbol estimates, and  
said first portion includes every first window of three windows of  
4 said block;  
said second portion includes every second window of three windows  
6 of said block;  
said third portion includes every third of three windows of said block

7. A method for performing turbo decoding comprising:  
2 a) reading out at least three different portions of a channel  
estimate block in substantially simultaneous fashion at least three different  
4 times;  
b) generating state metrics for each different portion during each  
6 different read out;  
c) storing a first set of said state metrics;  
8 d) calculating symbol estimates using said first set of estimates  
and a second set of state metrics, where said second set of state  
10 metrics is calculating using an initialization value calculated  
using a third set state metrics.



- The method as set forth in claim 7 wherein
- 2 a first portion from said at least three different portions includes every first window of three windows of said block;
  - 4 a second portion from said at least three different portions includes every second window of three windows of said block;
  - 6 a third portion from said at least three different portions includes every third of three windows of said block.

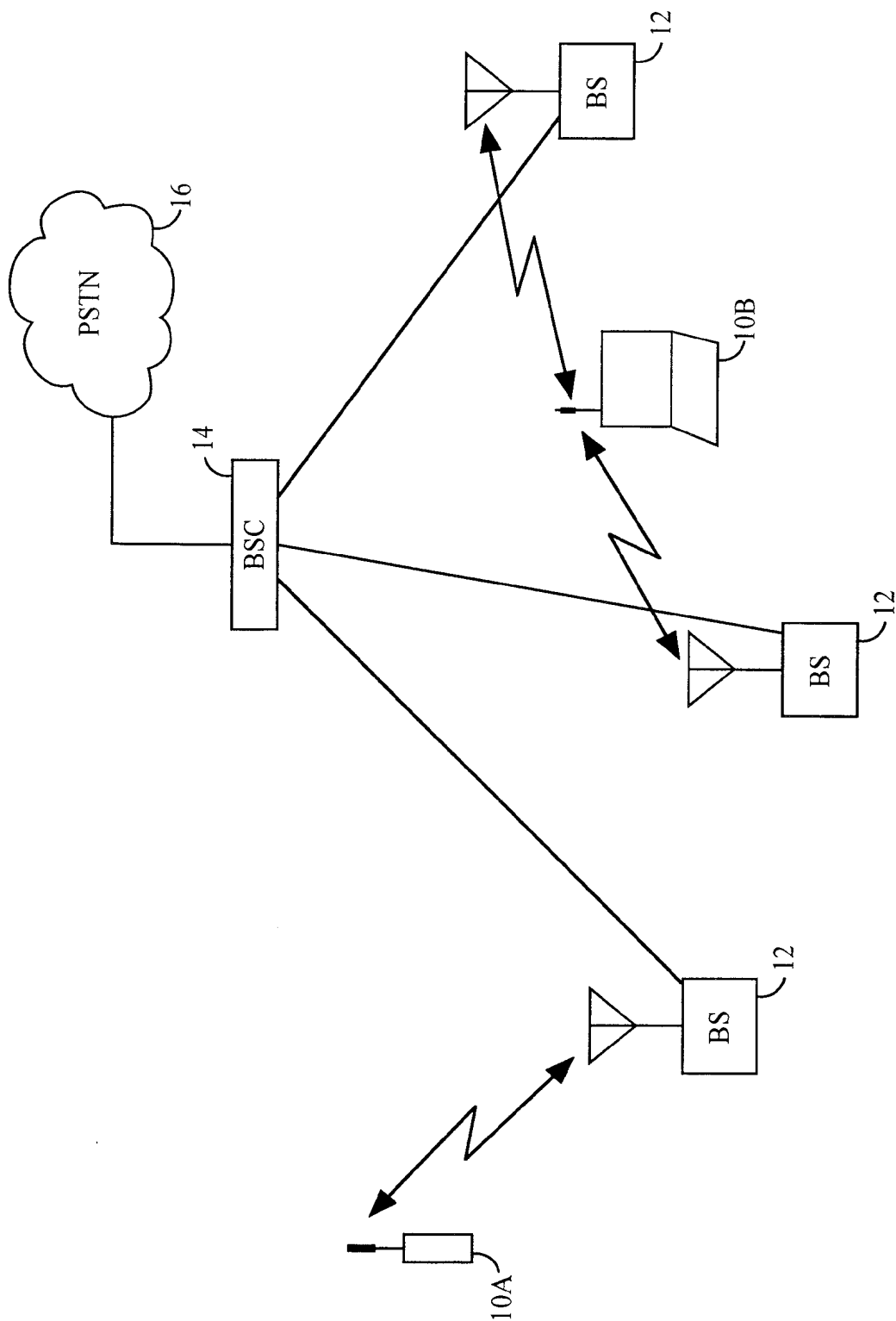


FIG. 1A

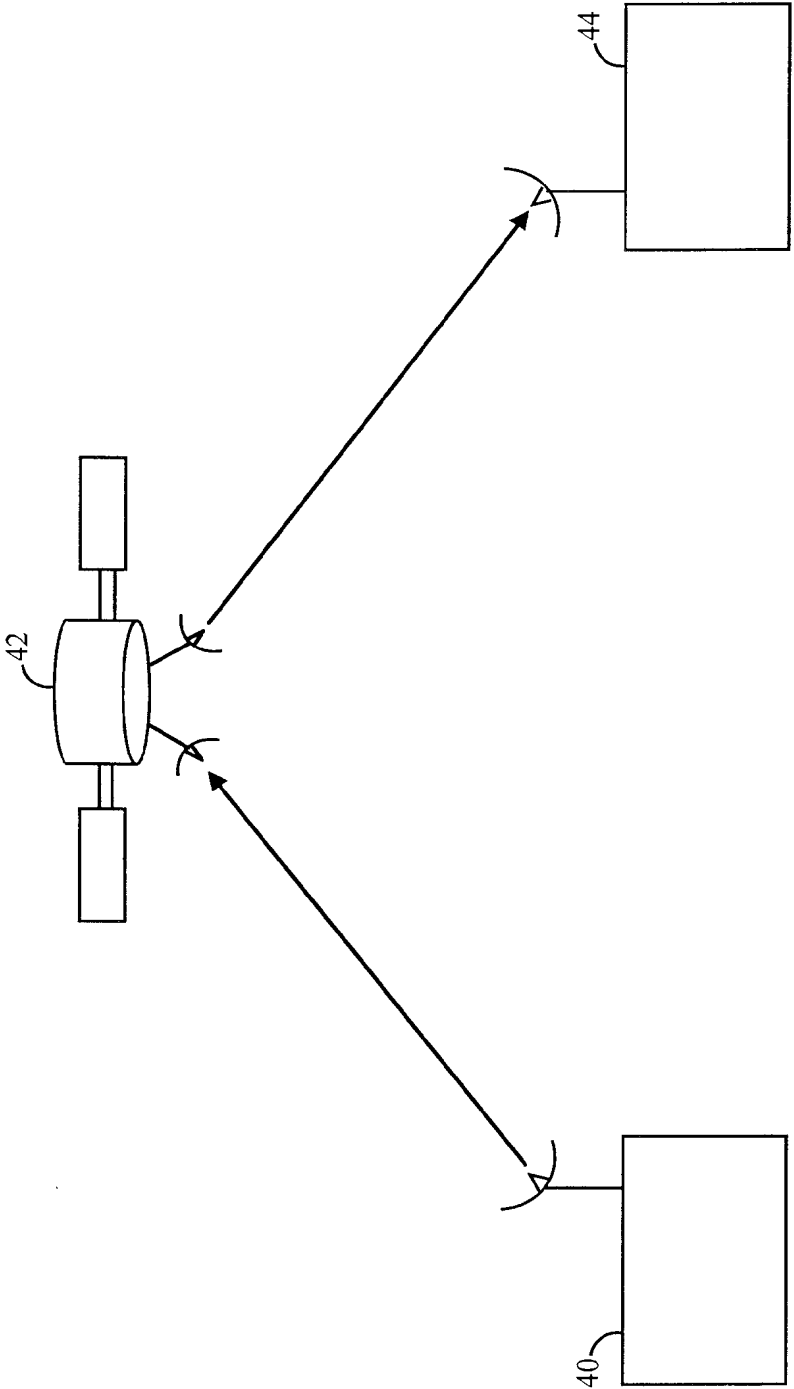


FIG. 1B

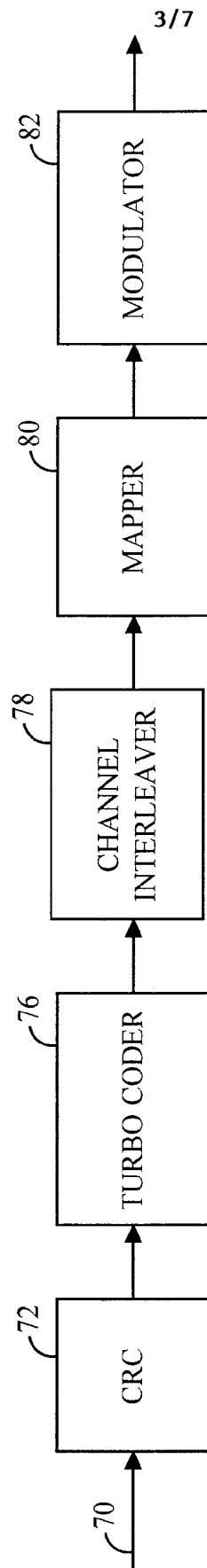
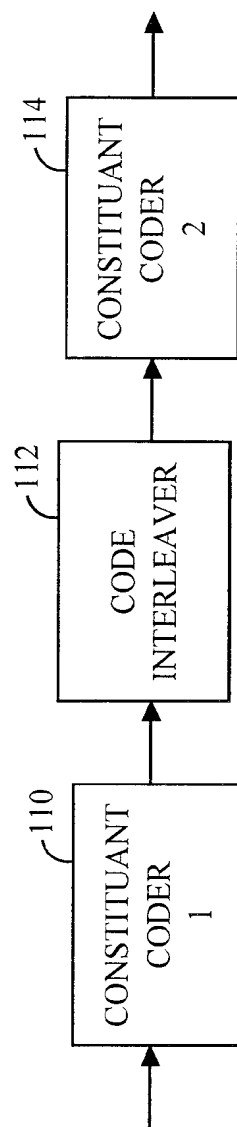
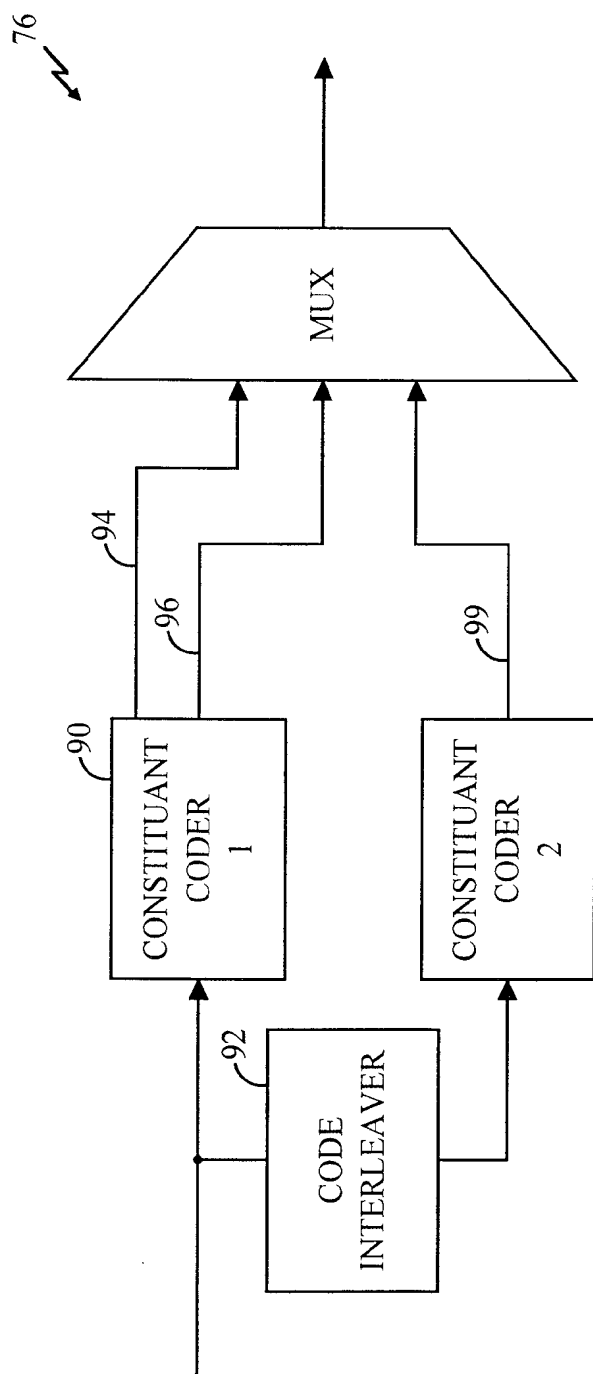


FIG. 2



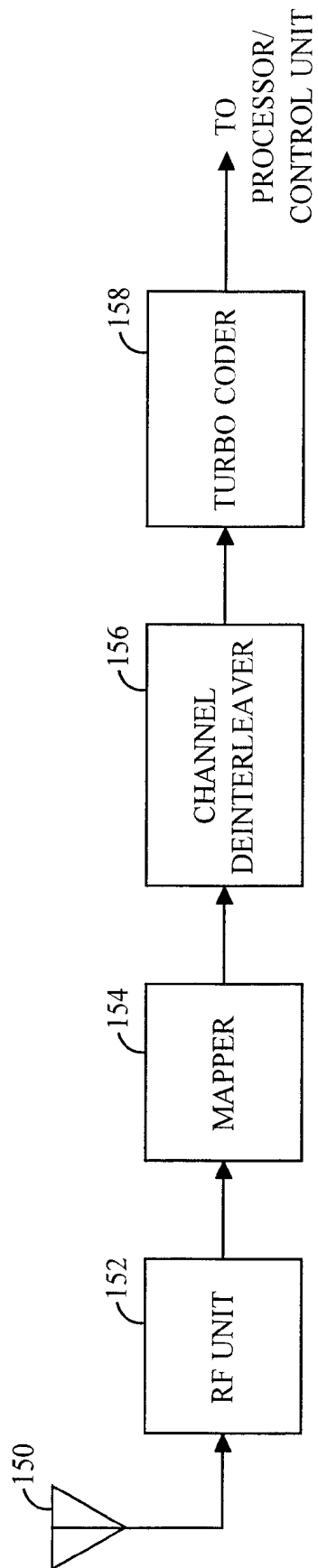


FIG. 4

6/7

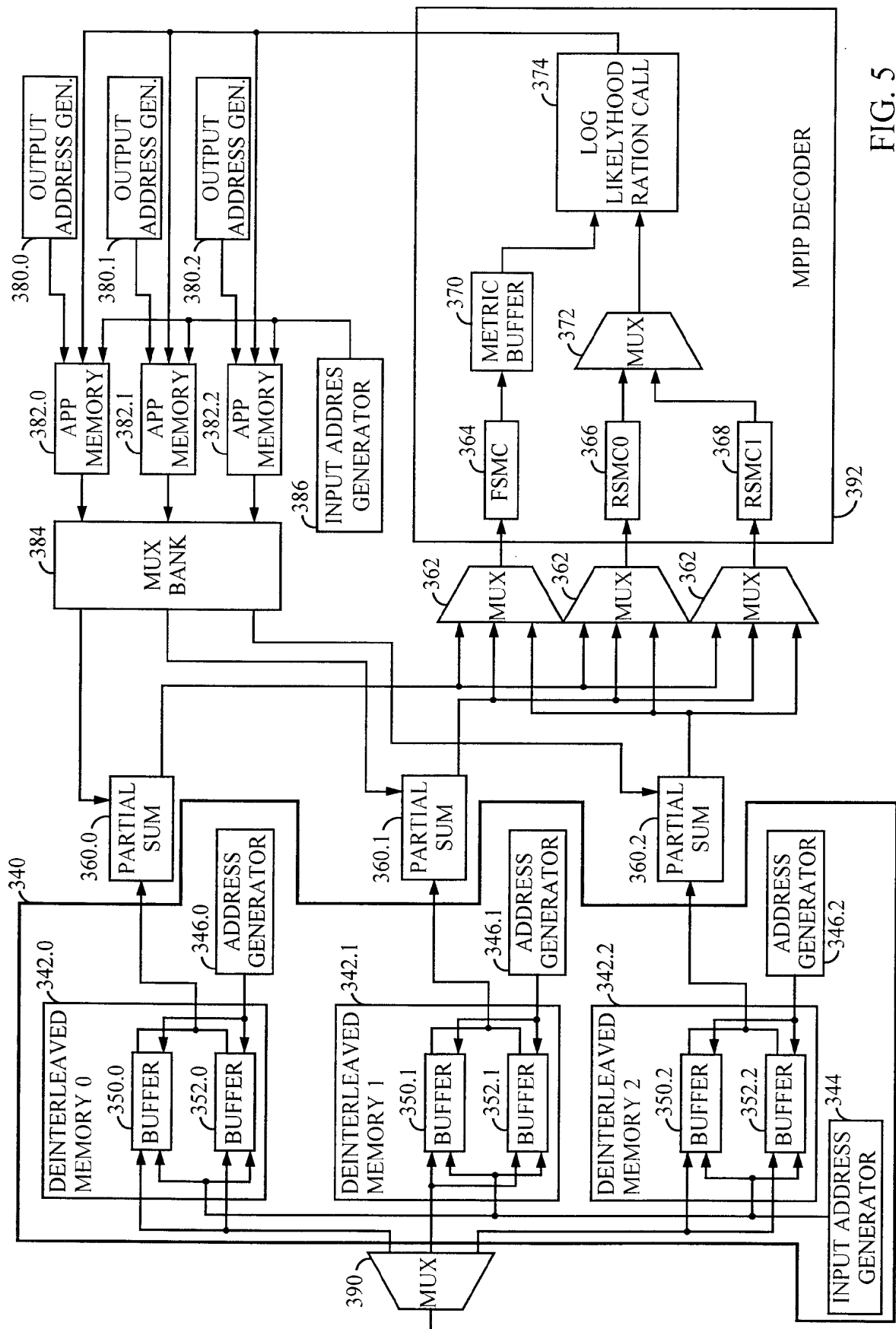


FIG. 5

7/7

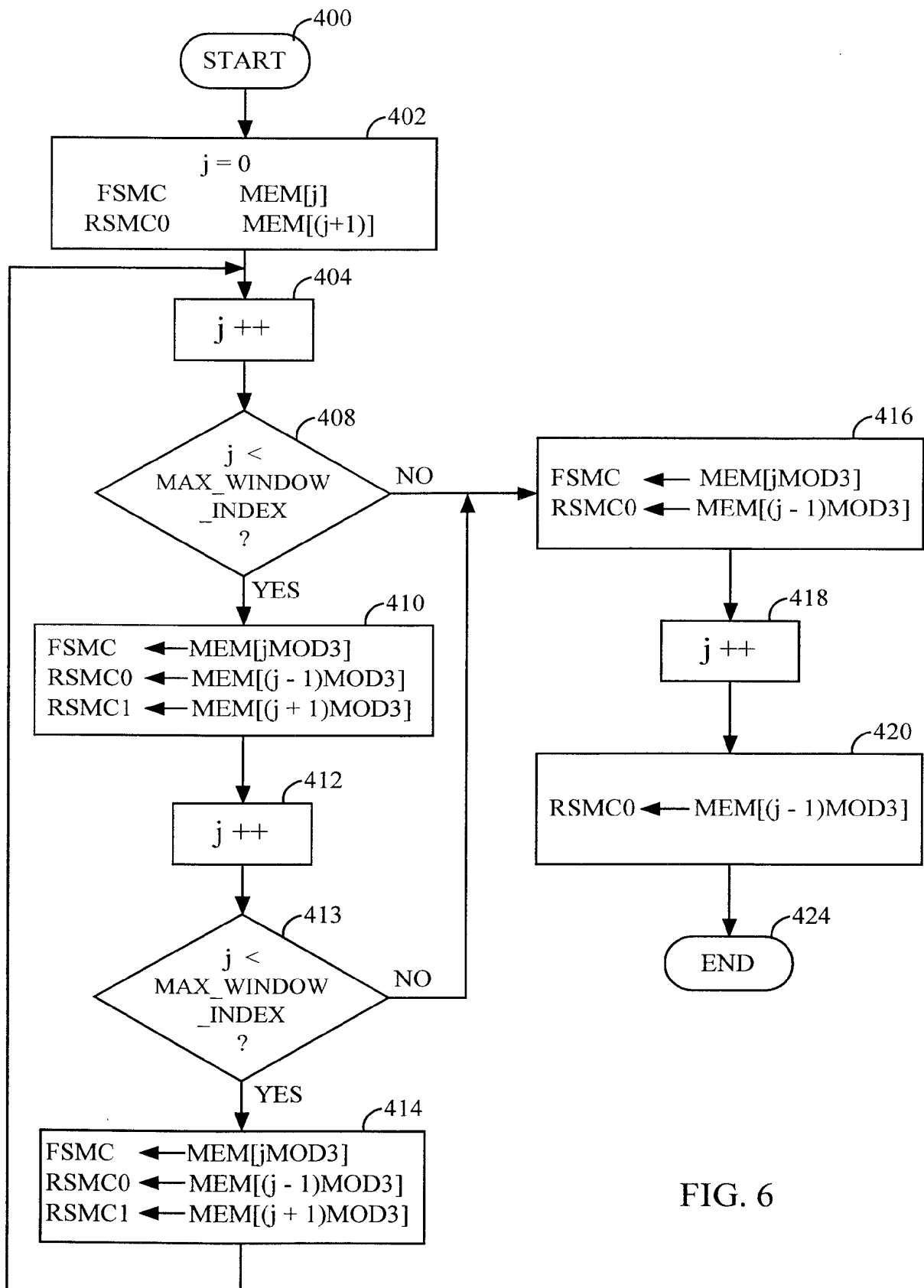


FIG. 6



# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 99/18551

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H03M13/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H03M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	VITERBI A J: "AN INTUITIVE JUSTIFICATION AND A SIMPLIFIED IMPLEMENTATION OF THE MAP DECODER FOR CONVOLUTIONAL CODES" IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, US, IEEE INC. NEW YORK, vol. 16, no. 2, page 260-264 XP000741780 ISSN: 0733-8716 the whole document ---	1,4,6-8
A	HSU J-M ET AL: "A parallel decoding scheme for turbo codes" INTERNATIONAL SYMPOSIUM ON SYSTEMS AND CIRCUITS ISCAS'98 31 May 1998 (1998-05-31) - 3 June 1998 (1998-06-03), pages 445-448, XP002124484 Monterey the whole document ---	1,4,7,8

-/--

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"S" document member of the same patent family

Date of the actual completion of the international search

2 December 1999

Date of mailing of the international search report

22/12/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel: (+31-70) 340-2040 Tx: 31 651 epo nl.  
Fax: (+31-70) 340-3016

Authorized officer

Ogor, M

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/18551

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 24850 A (MOTOROLA INC) 10 July 1997 (1997-07-10) page 12, line 14 - line 25 page 13, line 26 -page 15, line 2 figure 2 ---	1
A	EP 0 856 949 A (ALSTHOM CGE ALCATEL) 5 August 1998 (1998-08-05) figures 1,3 column 8, line 52 -column 9, line 51 ---	1
P,X	HALTER S ET AL: "Reconfigurable signal processor for channel coding & decoding in low snr wireless communications" IEEE WORKSHOP ON SIGNAL PROCESSING SYSTEMS 1998, 8 - 10 October 1998, pages 260-274, XP002124485 Cambridge, MA, USA the whole document -----	7,8

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 99/18551

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9724850 A	10-07-1997	US 5862190 A	19-01-1999
		BR 9607430 A	26-05-1998
		CA 2209083 A	29-06-1997
		CN 1176722 A	18-03-1998
		DE 19681214 T	15-07-1999
		FI 973535 A	27-08-1997
		FR 2743229 A	04-07-1997
		GB 2312816 A	05-11-1997
		JP 11501492 T	02-02-1999
		SE 9703096 A	29-10-1997
EP 0856949 A	05-08-1998	AU 5273098 A	06-08-1998
		CA 2225058 A	31-07-1998
		JP 10224236 A	21-08-1998